Characterization of green wastes' transformations occuring while composting

Caractérisation des transformations des déchets verts lors de leur compostage.

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Abstract

Though the process of composting offers technical advantages and leads to the production of compost used as amendment or fertilizer in agriculture, it often encounters some limitations due to a lack of control parameters and some difficulties to characterize the stabilization of organic matter.

In order to better understand the process and characterize the compost's stabilization, we studied green wastes'transformations occuring while composting at an industrial plant.

Characterization consisted in granulometric fractionation and chemical analysis of the fractions and the global solid : dry matter, organic matter, organic carbon, Kjeldahl nitrogen. Aqueous extractions of the solids have been realized and pH, chemical oxygen demand, Kjeldahl nitrogen and ammonium ions of the extracts have been measured.

The solid organic matter characterization shows it fast doesn't change except Kjeldahl nitrogen contents which have a sensitive relative evolution. The calculation of organic matter elimination rate describes well the biodegradation slowing down. The concentrations variations in the aqueous extracts are more sensible and chemical oxygen demand is indicative of the different steps of the process.

Résumé

Bien que le procédé de compostage offre de nombreux atouts techniques et conduise à la production d'un compost utilisable en tant qu'amendement ou fertilisant en agriculture, il présente un certain nombre de limites liées à une mauvaise connaissance de paramètres de contrôle et à certaines difficultés à caractériser la stabilisation de la matière organique.

Dans l'objectif de mieux comprendre le procédé et de caractériser la stabilisation de la matière organique, nous avons étudié les transformations de déchets verts traités par compostage sur site industriel.
La caractérisation a consisté en un fractionnement granulométrique et une analyse chimique de fractions et de solide global : matière sèche, matière organique,

carbone organique, azote kjeldahl. Des extractions en phase aqueuse des solides ont été réalisées et le pH, la demande chimique en oxygène, l'azote kjeldahl et l'ammoniac des extraits aqueux ont été dosés.

La caractérisation de la matière organique initialement solide montre que sa composition ne change presque pas à l'exception de sa concentration en azote dont la variation est plus sensible. Le calcul des taux d'élimination de la matière organique décrit bien le ralentissement de la biodégradabilité. Les variations de concentration dans les extraits aqueux sont en revanche plus significatives et l'évolution de la demande chimique en oxygène traduit bien les différentes étapes du procédé.

1. Introduction

The treatment of organic wastes by composting offers a few technical advantages which are for instance the possibility to treat a large range of quantities of wastes with a high or in the contrary a low level of technology. The characteristics of organic wastes, their moisture and their ability to biodegrate, favour the development of composting. Finally composting leads to the production of compost which may be used as amendment or fertilizer in soils. This last advantage also constitutes a present limit of the process that means the obligation for compost produced to satisfy a sufficient quality. This demand imposes to identify physical, chemical or microbiological parameters indicating for instance stabilisation of the product. A better control of the process also requires the identification of process control parameters.

The research of process control and stabilisation parameters has been the object of many studies. The wastes whose evolution during composting was studied were mainly solid wastes from animal husbandry, organic fraction from municipal wastes, municipal sewage sludge and green wastes. These were treated in industrial composting plants or in composting simulation pilots. These studies show it is sometimes difficult to determine a singular parameter that would be suitable for every organic waste. The concept of maturity also includes the specific use that will be made of the compost and it imposes to take into account in the parameter identification the future compost's application. However considering the kinetic decrease of the concentrations may be an indicator of stabilization and the determination of parameters describing this decrease could permit a better control of the process. Our study consisted in the characterization of the green wastes' transformations occuring during composting on an industrial plant and in the identification of parameters, between those already tested, which could be applicable to the green wastes. Assuming that most of the biological activity took place in the liquid film, we interested both in the global solid product and the aqueous extracts. By another way we prefered follow up parameters which could give later quantitative process informations. Granulometric fractionation has been realized and for every granulometric range, chemical parameters particularly some used in characterization of waste water have been experimented both on dried and ground solid and on aqueous extracts : organic matter (OM) and its main

components on solid, pH, chemical oxygen demand and nitrogen species (NK : Kjeldahl nitrogen, NH4$^+$: ammonium ions) of the aqueous extracts.

2. Literature review

In order to search stabilization or process control indicators, many different types of parameters have been tested.

Physical parameters such like temperature (Mustin[1]), odour (Mustin[1], Chanyasak et al[2], Jimenez and Garcia[3], Harada et al[4]) and colour (Jimenez and Garcia[3], Sughara et al[5]) have been experimented. If a low temperature, a black colour and absence of odours may characterize a stabilized compost, these indicators remain too imprecise to define the degree of stabilisation.

Chemical parameters have been measured on the global solid phase, humid or after drying and grinding or on the aqueous extracts obtained by a solid-liquid extraction of the composting product. The solubilization and transformation of organic matter by the microorganisms means at first the release, in the liquid film around the solid matter, of carbohydrates, amino and volatil acids, phenols (Hirai et al[6]) which will be biodegraded and transformed in carbon dioxide. This mineralization of the organic matter is responsible for the decrease then the increase of pH which have been already wide exposed (Jimenez and Garcia[3], Harada et al[4], Inbar et al[7]). The decrease and stabilization of the global organic matter and the release of the acids have been studied by Garcia et al[8] and Insam et al[9]. Inbar et al[10], Dinel et al[11] and Mathur et al[12] associated the concentrations of the dissolved components to optic density of aqueous extracts at 280, 465 and 665 nm and found they were well corelated to the composting time. Concentrations of low molecular weight amino and volatil acids inferior to 1 mg/g dry compost would indicate the stabilisation of the compost (Chanyasak and Kubota[13]). Bernal et al[14] found for different composts that a value of 1,7 % of dissolved carbon was indicative of stability. The mineralization of the organic matter leading to the production of carbon dioxide causes a decrease of the global chemical oxygen demand (COD) which yet may be sensible in mass and not sensible in concentration. A decrease of COD is for Mustin[1] (COD < 350 mg/g of compost) and Insam et al[15] indicative of stabilisation whereas for Godden[16] this decrease isn't always clear.

Nitrogen transformations through organic matter mineralization, nitrification and denitrification have been often studied too. Some authors gave indicative concentrations of NK, NH4$^+$ (NH$_4^+$ < 0.04 % dry matter for Zucconi and De Bertoli[17], absence of NH$_4^+$ for Harada et al[4] in animal wastes' composts, N-NH$_4^+$ < 0,04 % for Bernal et al[14] in sewage sludges' and animal wastes' composts), NO$_3^-$ (NO$_3^-$ > 300 mg/kg dry compost from municipal sewage sludge, Forster et al[18]) and value or tendance of NH$_4^+$/NO$_3^-$ (NH$_4^+$/NO$_3^-$ < 0,16 for Bernal et al[14], NH$_4^+$/NO$_3^-$ between 0,03 to 18,9 for Hirai et al[6] and it must decrease for Insam et al[15]). For Mathur et

al[19] no particular level of nitrate or its ratio to ammonia can be relied as indicator of compost biomaturity.

Taking into account both elimination of carbon and nitrogen, C/N ratio has been wide employed as indicator of maturity. For instance after tests on different sewage sludges' and animal wastes' composts, Bernal *et al*[14] measured a C/N value of 12 as maturity level. Many authors (Harada *et al*[4], Chanyasak and Kubota[13], Wong and Chu[20]) don't agree with C/N indication particularly because of its large fluctuation according to the initial waste's nature. Godden[16] and Van de Kerkhove[21] prefer consider its evolution with time than a particuliar value. The C/N ratio has been measured in the aqueous extracts too and values around 5-6 have been proposed by Chanyasak *et al*[2], Chanyasak and Kubota[13], Hirai *et al*[22], Iannotti *et al*[23] and Canet and Pomares[24]. A too high concentration of nitrogen in the initial waste (municipal sewage sludge) would exclude its utilisation as indicator (Inbar *et al*[7]).

For Inbar *et al*[10], the stabilisation of aqueous extracts conductivity, whose Ca^{++}, Mg^{++} and NO_3^- are mostly responsible for, may be indicative of stabilisation too. Yet Avnimelech *et al*[25] showed the evolution of the aqueous extracts conductivity may be difficult to interpret and must account for the complexation degree of anions and cations with organic matter.

The aerobic biological activity can be described by measure of microbiological parameters such like the oxygen consumption or carbon dioxid production (Mustin[1], Forster *et al*[18], Mahmood *et al*[26], Iannotti *et al*[27],), the enzymatic activity (Godden[16], Forster *et al*[18]). Bacteriological identification and numeration have been studied by Insam *et al*[9].

The biochemical composition of the solid phase and its specific properties characterizing its stabilization level have been studied too. So after a chemical extraction, cellulose, hemicellulose and lignin concentrations have been measured according to Van Soest[28] and Adani[29] fractionation methods and associated to carbon dioxide production (Linéres[30]). An indice of biological stabilisation (BSI) has been defined which allows to associate potential of mineralization to biochemical composition. Humic substances' increase (Garcia *et al*[8], Mahmood *et al*[26], Chefetz *et al*[31]) and measure of distinct fractions as humic and fulvic acids, non humic fractions and calculation of different ratios have been tested by Inbar *et al*[7], Forster *et al*[18], Roletto and Barberis[32], De Nobili and Petrussi[33], Ciavatta *et al*[34], Govi *et al*[35]. The increase and stabilisation of the cation exchange capacity (CEC) is often recognized as a good indicator too : CEC > 100 meq./100 g O.M. (Organic Matter) for animal wastes (Harada and Inoko[36, 37]) and municipal wastes (Van de Kerkhove[21]), CEC > 20 meq./100 g OM for green wastes (Mahmood *et al*[26, 38]). Inbar *et al*[7, 39] and found a corelation between CEC and humic substances increases. The difference between extractible lipids in diethylether and in chloroform has been proposed by Dinel *et al*[11] as a maturity indicator. Biochemical changes of the organic matter and particularly its aromatization may be characterized by spectrometric parameters such like IR and CPMAS ^{13}C-RMN (Cross Polarization Magic Angle Spinning) (Inbar *et al*[7, 39] and Chefetz *et al*[29]). Thermogravimetric methods have been experimented by Blanco and Almendros[40].

Chemical parameters have been measured on the alcalin extracts : IEF (isoelectric focusing) by Ciavatta *et al*[34] and Govi *et al*[35], UV absorption by Prudent *et al*[41].

Finally these chemical and biochemical transformations increase agronomic quality of composts. Phytotoxicity, germination (Bernal *et al*[14], Blanco and Almendros[40], Zucconi *et al*[42], Baca *et al*[43]) and growth (Inbar *et al*[10], Bernal *et al*[14], Iannotti *et al*[23], Chefetz *et al*[31], Mahmood *et al*[38], Blanco and Almendros[40], Baca *et al*[43]) tests have been improved.

3.Materials and methods

3.1. The composting plant

The plant collects green wastes brought by inhabitants of the nearest agglomerations and public or private professionals. These green wastes compose themselves of branches, leaves, weeds, cut grass. These are weighed then ground and stacked in windrows on a cemented uncovered area. Seven windrows take place on the area. Every windrow has a trapezoïdal cross section (30 m x 10 m and 3 m high) and an initial mass of 500 to 1 500 tonnes. The windrows are turned every 15 to 21 days by a mobile equipment. For the first three months, in case of insufficient moisture, water may be sprayed above. After six to seven months composting, the product is separated, using two rotative sieves of 10 and 20 mm, to the undersized, the compost, the middlesized, the mulch and the oversized which is recycled in grinding at the beginning of the process. The compost is stocked on a covered area.

Transformations occuring in three windrows of green wastes stacked in february (2-97), march (3-97) and april (4-97) 1997 have been characterized. The experiment last about eight months from grinding to the final refining. The three windrows have been sampled every time they were turned (8 to 10 times) and the analysis have been realised for every sample.

3.2. On sites sampling and measurements

Temperature has been measured and samples have been collected every time the windrows were turned. Temperature was measured before turning by introduction of a thermometer probe in about twenty points at the surface of the windrow to a depth of 1,50 m and the mean temperature has been calculated.

When the mobile equipment is going through the windrow, it turns about 30 cm larg of the pile. At every passage, we collected manually about 10 kg of product in the cross trapezoïdal section. At the end, the global sample (# 300 kg) has been reduced (by successive division in identical portions) to about 30 kg.

3.3. Solids and liquids preparation for analysis

We supposed solids' transformations were different whether the products were constitued in big or little fragments. More, fractionation allowed to get a more representativ sample for analysis. Finally in order to characterize the aqueous extracts, fractionation was realized on humid solid. Then, using two vibrating plane sieves with square meshs of 6,3 mm and 25 mm, about 10 to 20 kg of humid product were separated to four fractions : F1 < 6,3 mm, 6,3 mm < F2 < 25 mm, 0 < F3 < 25 mm, F4 > 25 mm. Half part of each fraction except F4 has been dried at 40°C then ground to particles < to 500 µm. The big dimensions of solids of F4 exclude to grind it with our equipments but its low percentage in regard of the total humid weigh (< 10 %) led us to consider the solid inferior to 25 mm as the global product. The second half parts of F1, F2, F3 have been extracted three times in series by deionized water (100 g / 500 ml). Each extraction last 4 hours and the three extracts have been mixed together and filtered at 8µm.

3.4. Analysis of solid and aqueous extracts

3.4.1. Analysis of solids

In order to reduce analysis' errors due to heterogeneity of the global sample (0/25), we measured the interesting parameter for every granulometric fractions, (0/6,3) and (6,3/25), and in respect of their ponderate contribution we calculated by addition the parameter which should have been measured on the global solid. This method has been validated before practise with ten samples for which we verified :

$$G_{0/25} * (1 - H_{0/25}) * P_{0/25} = G_{0/6,3} * (1 - H_{0/6,3}) * P_{0/6,3} + G_{6,3/25} * (1 - H_{6,3/25}) * P_{6,3/25}$$

G_i humid weight percentage of Fi above the global humid weigh,
H_i moisture of fraction Fi,
P_i physico-chemical parameter measured on fraction Fi.

Dry matter has been measured by drying at 105°C and organic matter at 550°C for 6 hours. Global ash content has been computed as reference to estimate dry matter content at every time. Carbon has been measured by combustion at 1200°C and absorption of emissions of CO_2 and H_2O. Total carbon includes organic carbon and a part of mineral carbon volatil at 1200°C. We chose to estimate organic carbon by supposing it was equally distributed among organic matter at 550°C and volatil matter between 550°C and 1200°C. Kjeldahl nitrogen has been measured by fitting standard methods of water analysis to dried ground solids. So, Kjeldahl nitrogen is measured by mineralisation at boiling of 1 g solid in 25 ml sulfuric acid. The reaction is catalysed by $CuSO_4$, 5 H_2O, K_2SO_4 (Kjeltabs CK). When the mineralization is finished, the sample is cooled, 60 ml water are added and it is basified by addition of 120 ml of sodium hydroxyde 30 % . Then ammonium is measured according standard method of water analysis.

In order to calculate the percentage of elimination of dry matter, we have to

estimate the total weight of the windrow we can't measure. We supposed the total mass of mineral matter (MM) remained constant during the process, $mMM_0 = mMM_t$, then we calculated the total mass of dry matter mDM. The organic matter mass (mMO) can be calculated too.

mMM_i, mMM_0, mMM_t, mineral matter masses in fraction F_i and in global product at the beginning and at t,
mDM_i and mDM, dry matter masses of fraction F_i and global product,
OM_i, organic matter concentration in fraction F_i,
G_i, ratio of humid weight of F_i above total humid weight,
H_i and H, moisture of fraction F_i and of global product,
mH humid mass of global product,
mOM_i and mOM, organic matter masses in fraction F_i and in the global product.

$mMM_i = mDM_i (1 - OM_i)$,
$mMM_0 = mMM_t = \Sigma_i mMM_i = \Sigma_i mDM_i \times (1 - OM_i)$,
$mDM_i = mH \times G_i \times (1-H_i)$,
$mMM_0 = mH \times \Sigma_i G_i \times (1 - H_i) \times (1 - OM_i)$,
then we calculate mH, mD_i, mOM_i, mDM and mOM:
$mDM_i = mH \times G_i \times (1 - H_i)$, $mDM = \Sigma_i mDM_i$,
$mOM_i = mDM_i \times OM_i$, $mOM = \Sigma_i mOM_i$.

3.4.2. Analysis of aqueous extracts

After filtration at 8µm, the aqueous extracts have been analysed : pH, COD, N-NK and NH_4^+ have been measured according standard methods of water analysis.

4. Results and discussion

4.1. Temperature

From 20 to 150 days old the temperature in the compost is superior to 70 °C. From 150 to 200 days old the temperature slowly decreases of about 3 to 5 degrees which may mean a decrease in the degradation transformations.

4.2. Solid phase analysis

4.2.1. Granulometric characterization

The global humid product has been separated by sieving into three granulometric fractions : F1 < 6,3 mm, 6,3 mm < F2 < 25 mm, F4 > 25 mm. We can observe (fig.1) the product gets always finer, that means the increase of the finer fraction and in the contrary the corresponding decrease of the fraction 6,3/25. In spite of grinding effect of turning and aerobic degradation, the upper fraction F4 remains

fast constant in weight. This fraction accounts for less than 10 percent of the total weight of humid solid and the fraction 0/25 has been considered as the global solid.
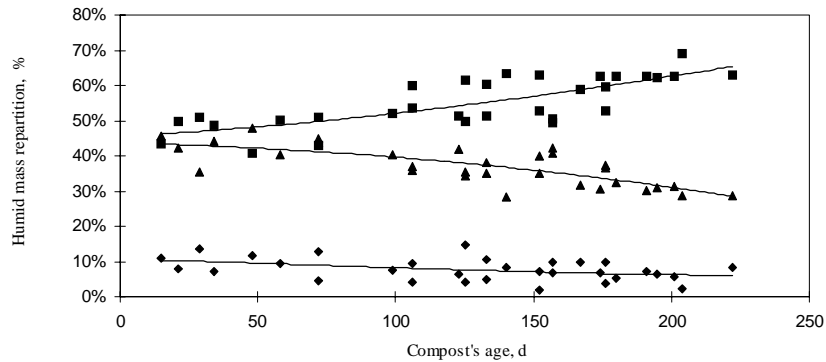

Figure 1.
Granulometric fractionation of the global humid composting product:
(■) fraction 0 / 6,3 (mm); (▲) fraction 6,3 / 25 (mm); (◆) fraction > 25 (mm)

4.2.2. Moisture concentration

During the first month of composting, moisture of the global solid is between 45 % to 55 %. This moisture remains constant, 47 % to 50 % at the end of the treatment, which may be explained by water bringing from atmospheric precipitations and human process control. The moisture of the different fractions is around 50 % at the beginning. It remains constant for the fractions 6,3/25, slightly increases for the fraction > 25 mm and it decreases to 45 % in 200 days for the fraction 0/6,3.

4.2.3. Dry matter elimination

Measures of Gi, Hi and OMi for every fraction and application of formulations explained in § 3.4.1 allow to calculate dry matter masses and their evolutions. Dry matter elimination is fast constant all along the 200 days process though we can suppose it slowly decreases at the end (fig.2). For the three, dry matter elimination rates are around 15 to 25 % at the end of the experiment.
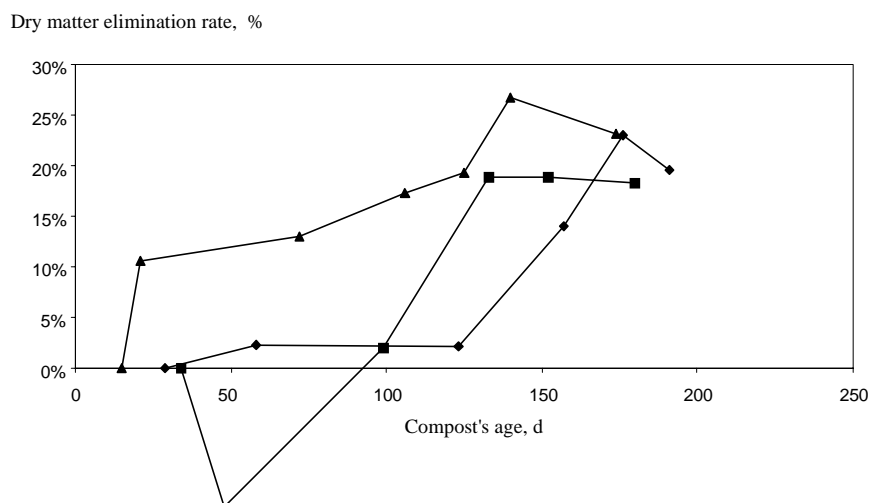
Dry matter elimination rate, %

Figure 2
Global dry matter elimination rate for the windrows: (◆) 2-97; (■) 3-97; (▲) 4-97

4.2.4. Organic matter concentrations and masses

After grinding the organic matter concentrations of the 0/6,3 and 6,3/25 fractions, in the three windrows, are respectively around 55 % and 78 to 83 %. The smaller concentration of the fraction 0/6,3 is due to the presence of mineral matter as fragments of soils. The concentration of organic matter in the fraction 6,3/25 remains constant whereas it decreases of 5 to 10 % in the finer fraction (fig.3). The organic matter content of the fraction > 25 mm remains constant too, OM = 0,85. The organic matter content of the global solid (0/25 fraction) decreases slightly from 65 to 55 %. Organic matter concentration decreases too slowly to be considered as indicator of stabilisation and more it depends closely of the initial wastes. Yet the measure of organic matter may be interesting if dry matter mass has been estimated. In that case, global organic matter masses decrease and the organic matter elimination rate is closely tied to the elimination rate of dry matter. The evolution of that rate particularly at 200 days allows to conclude the biodegradation is diminishing. Yet the elimination rate has been calculated by supposing the global mineral matter mass was constant which will have to be confirmed in experimental controlled conditions, for instance in a composting simulation pilot.
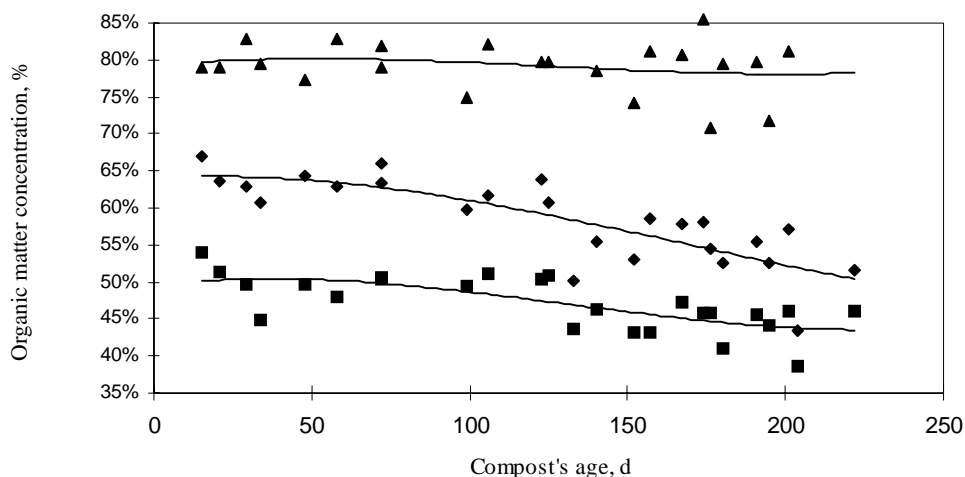
Figure 3
Organic matter concentration in solid fractions and global solid
for the three windrows 2-97, 3-97, 4-97 :
(■) fraction 0 / 6,3 (mm); (▲) fraction 6,3 / 25 (mm); (◆) global solid

4.2.5. Organic carbon and Kjeldahl nitrogen concentrations in the global solid

Organic carbon concentrations and organic matter concentration are closely fied and exhibit a some low decrease in fraction and in the global product. In global product organic carbon concentration decrease from 35 or 30%. In the contrary of carbon concentrations which are the sames in every windrow of compost, Kjeldahl nitrogen concentrations are superior in case of windrow 4-97 than in windrows 2-97 and 3-97. This superiority explains itself by the higher concentration of 4-97 in more biodegradable green wastes such like grass, leaves ... We can observ a sensitive but regular increase in nitrogen from 0,8 to 1,1 % for 2-97. For both carbon and nitrogen, we can't observ different rates in the evolution of concentrations.

The small variations observed in the transformations of the solid, in particular in the concentrations in organic matter and its main components and in spite of the higher relative variations of nitrogen, don't allow to consider them as interesting parameters to control the composting process or indicate organic matter stabilisation. Calculation of dry matter masses and measure of organic matter concentrations allow to calculate organic matter masses and describe their evolution. So we showed the organic matter elimination rate decreased at the end of the treatment.

4.3. Liquid phase characterization

Only the analysis results of aqueous extracts of the fraction 0/25 have been

exposed, we can yet mention the concentrations measured in the aqueous extracts of the fractions 0/6,3 and 6,3/25 were equal to the concentrations measured in aqueous extracts of the fraction 0/25. Elsewhere we calculated concentrations of COD, N-NK and N-NH$_4^+$ in respect of the global volum of biofilm ($V_{biofilm}$ = mDm x H). As the moisture is around 50 % these concentrations are fast equal in respect of global dry matter. Finally, for a same age of the three composts, we can notice a large dispersion of pH, COD, N-NK and N-NH$_4^+$ values. These differences may be explained by their specific nature: pieces of wood, leaves, cut grass ... which are more or less soluble in aqueous phase in spite of their same origin.

For the windrow 4-97, we observed (fig.4), at the begining of the treatment, the acidification of the aqueous extracts which can be explained by the hydrolysis of organic matter and release of organic acids (Jimenez and Garcia[3], Inbar *et al*[7], Harada *et al*[4]). After that first step of acidification, the pH increases which we observed in the three windrows (fig.4). This increase from values between 6 at 7 to values around 8 at 9 is corresponding to the release of ammonia and other basic components in the liquid film, and the elimination of organic acids.
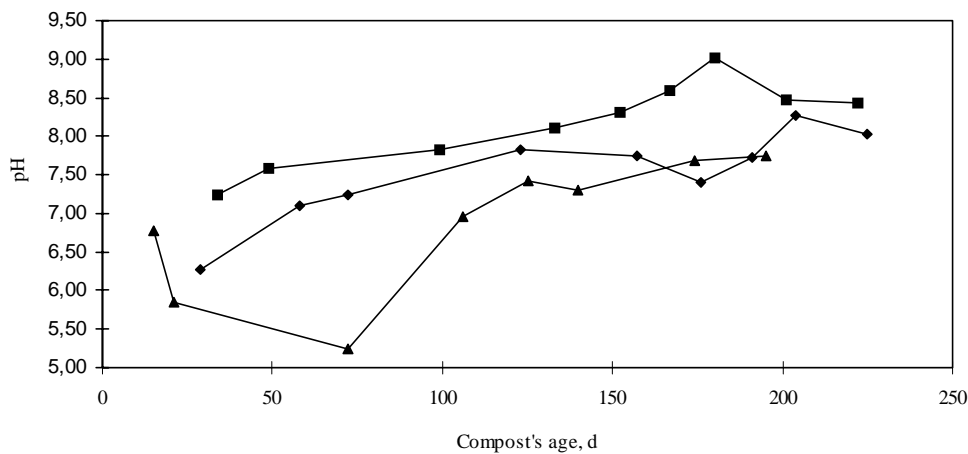

Figure 4
pH of the aqueous extracts for the windrows: (◆) 2-97; (■) 3-97; (▲) 4-97

The evolution of pH is intimately tied to release and remove of organic matter in the biofilm surrounding the solid phase. A sensitive parameter of that organic matter evolution may be the COD concentration in the biofilm (COD has been measured in the aqueous extracts then expressed in respect of moisture that means the global volume of biofilm in the compost). COD (fig.5) is first increasing in case of windrow 4-97 as the pH was decreasing in the same time which improves their great corelation. For the three windrows, after that first increase for the windrow 4-97, we observe the decrease of COD concentration in the biofilm. If we keep in mind the moisture in the windrows is slightly decreasing, the COD decrease is as much higher in mass. After a step of transfer from solid to liquid of organic matter which is

responsible for the first increase, the consumption of that dissolved organic matter explains the second diminution step. At the end of the treatment we can see a slight back rise of COD which may be due to a continuous transfer but a falling down microbiological consumption : dissolved organic matter is not biodegradable or necessary conditions for microbiological metabolism aren't gathered anymore. We can notice the high COD concentrations in the biofilm, 10 to 60 g / l, still higher for the windrow 4-97 which may be explained by the green wastes' composition in april, containing more cut grass and leaves whose soluble fraction is greater than for branchs... .
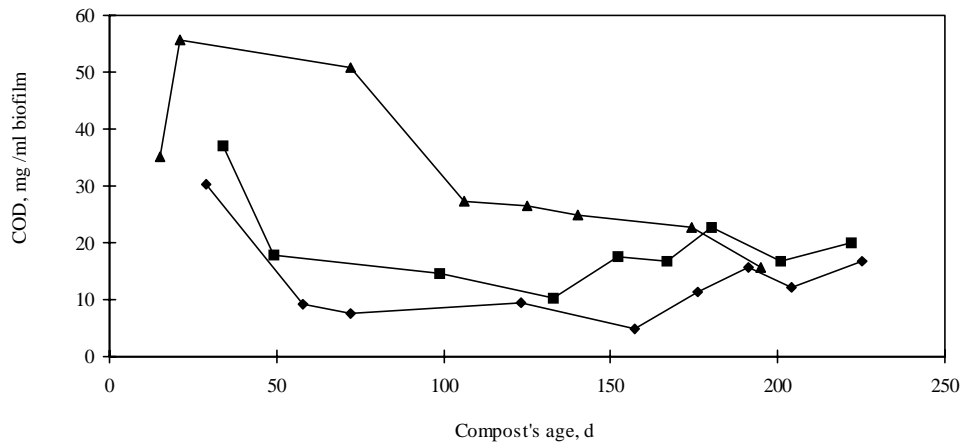

Figure 5
COD concentrations in the biofilm for the windrows: (◆) 2-97; (■) 3-97; (▲) 4-97

Kjeldahl nitrogen and ammonium concentrations (fig. 6, fig. 7) have fast equal evolution as COD concentration : a first increase for windrow 4-97 then a decrease for the three piles and finally a back growth at the end of the treatment. Kjeldahl nitrogen and ammonium concentrations are respectively in the range of 0,2 to 1 g.l^{-1} and 0,1 to 0,8 g.l^{-1} for the windrows 2-97 and 3-97. They are superior for the windrow 4-97 : 1,2 to 2,2 g.l^{-1} for N-NK and 0,6 to 1,2 g.l^{-1} for $N-NH_4^+$. Nitrogen concentrations are well corelated to the COD concentrations. So we can share the first one hundred days corresponding to the biggest product transformations from the second part corresponding to slower matter conversions then the final part which shows the slowing down microbiological metabolism.
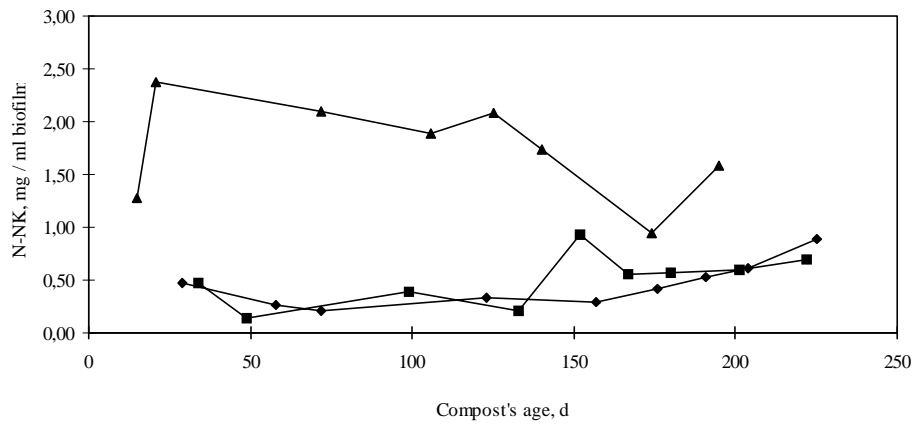
Figure 6
Kjeldahl nitrogen concentrations in the biofilms
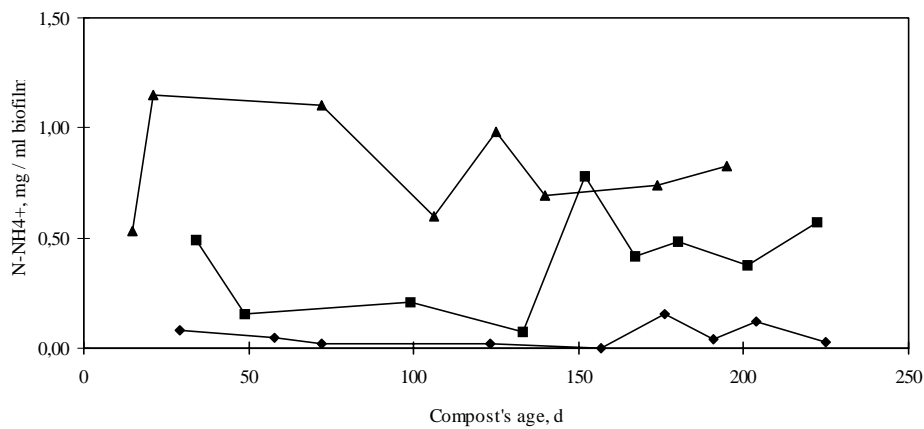*for the windrows:(◆) 2-97; (■) 3-97; (▲) 4-97*

Figure 7
Ammonium concentrations in the biofilm for the windrows :
(◆) 2-97; (■) 3-97; (▲) 4-97

We can conclude the characterization of the dissolved organic matter can be used to describe the decreasing transformations of the composting product and so it can provide process control parameters. Yet it could be interesting to measure separately which quantity of organic matter is transfered and which one is microbiologicaly consumed in the same time. Such an approach would allow to quantify the different steps of the process : increasing then decreasing transfer from solid to liquid followed by the increase then the decrease of the biological consumption.

5. Conclusions

Through the characterization of green wastes' transformations occuring while composting process, that study had two main objectives : a better understanding of the composting process and the identification of process control and organic matter stabilization parameters. So we showed :

- the concentrations measured on the solid for instance in organic matter, organic carbon and nitrogen vary too lowly or/and slowly to be considered as process control or organic matter stabilization parameters,

- by calculation it is possible to determine organic matter masses and elimination rates which well describe the final slowing down of degradation, conservation of mineral matter mass will have to be verified in controled experimental conditions,

- the concentrations measured on the aqueous extracts are more sensitive and their variations well corelated. So the pH and COD, N-NK and N-NH$_4^+$ concentrations describe well the process and the stabilization of the organic matter at the end of the treatment. After a first increase of COD and nitrogen contents corresponding to the transfer of organic matter from solid to liquid phase, the biological consumption of organic matter is responsible for their diminution. Their back increase at the end of the treatment may be due to the pursuit of the transfer whereas biological consumption stopped. We have to keep in mind the slowing down degradation may be caused by depletion of nutrients like carbon or nitrogen but water too, which doesn't mean the product is stabilized.

- the single control of COD could be used as stabilization indicator and process control parameter. Yet that type of study will have to be realized for other wastes like waste water sludges, manure,

- it could be interesting to quantify separately the transfer and the biological consumption.

6. References

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